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(54) IMPROVEMENTS IN OR RELATING TO AIR INTAKE DEVICES FOR FANS OR COMPRESSORS

(71) We, SOCIETE NATIONALE D'ETUDE ET DE CONSTRUCTION DE MOTEURS D'AVIATION, a French Body Corporate, of 150 Boulevard Haussmann, 75-Paris, France, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to the attenuation of noise propagating upstream through the air intake of a fan or compressor, and relates more particularly to aircraft turbojet engines.

It is well known that in order to reduce the noise produced by an aircraft jet engine when the aircraft is flying close to the ground, that is to say after take-off and just before landing, it is necessary to attenuate not only the noise emitted by the propulsion jet and possibly that produced by the fan and travelling downstream, but also the noise produced inside the jet engine and propagating upstream through the air intake. It is equally well known that a highly effective means of attenuating this latter noise component consists in exploiting the property possessed by sonic flows so that they do not enable acoustic disturbances to propagate upstream by arranging in the air intake a structure which creates in the air flow one or more sonic throats. Tests have shown that attenuation of overall noise levels, in excess of twenty decibels can be obtained in this fashion, the residual noise propagating to the exterior upstream of the throat or throats, being chiefly transmitted by the boundary layer or layers. The structure will advantageously be retractable in order to reduce the losses occurring in the cruise condition.

In the known embodiments, this structure occupies a certain amount of axial space in the intake, making it necessary to lengthen the latter. For example, in British Patent No. 1,171,508 the structure is an annular, elastic, inflatable wall which, in the rest condition, follows the normal configuration which the air intake has in cruising flight and, once inflated, forms a convergent, divergent profile defining a sonic throat in the air flow; the convergent, divergent profile should sufficiently reduce the flow cross-sectional area of the intake to define the sonic throat, and this means that the inflatable wall must have an adequately large axial length.

The aim of the present invention is an air intake for a fan, which, as in said British Patent, has an inflatable structure designed to create a sonic flow in order to attenuate the noise component propagating upstream, at the same time having the advantage that it occupies only a very short length of the intake whilst securing a good aerodynamic performance.

In accordance with the invention, there is provided an air intake device for supplying air to a fan or compressor, said device having an inflatable structure designed to create a sonic flow in order to attenuate the noise component propagating upsteam, said structure comprising a plurality of blades whose lateral faces are constituted by elastic walls capable of being deformed under the action of at least one inflatable body in order to create a sonic throat or restriction between one face of each blade and the adjacent face of a neighbouring blade, the throat or restriction acting to attenuate noise propagating upsteam.

This arrangement furthermore offers the advantage of making it possible (for example by blowing air from the trailing edges of the blades of the structure, or by sucking away the boundary layer) to control the air flow around these blades and thus to reduce:

—the increase in downstream-propagating noise, due to the increase in the wake tur-

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bulence;
—the transmission of noise through the boundary layers.

The pressure to which the structure is inflated will advantageously be variable making it possible to adapt its shape to the flow rate through the air intake in order to achieve the maximum acoustic attenuation and the minimum losses, under the operating conditions selected.

In the case where the fan is designed to co-operate with intake guide vanes, the blades will advantageously be orientated so that the fixed vanes, in the deflated condition, act as intake guide vanes vis-à-vis the fan.

The invention will now be further described by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a schematic axial half-section of the front of an aircraft turbojet engine whose air intake comprises a set of guide vanes with inflatable blades in accordance with the invention;

Figure 2 is a partial sectional view on the line II-II of Figure 1;

Figure 3 is a partial view on a larger scale, in the form of a developed cylindrical section, showing the blower blading and the fixed vanes in the deflated state;

Figure 4 is a view similar to that in Figure 3, showing the fixed vanes in the inflated state;

Figure 5 illustrates on a yet larger scale, an inflatable blade, the view being a perspective one, partially cut away;

Figure 6 is a transverse sectional view of an inflatable blade equipped with a device for blowing air from the trailing edges of the blades;

Figure 7 is a view similar to that of Figure 6, showing an inflatable blade of adjustable shape;

Figure 8 is a view similar to that of Figure 7, showing another embodiment;

Figure 9 is a view similar to that of Figure 1 showing a variable-pressure device;

Figure 10 illustrates the pressure-regulator element of this device viewed in longitudinal section, on a larger scale; and

Figure 11 is a view similar to that of Figure 10 showing the regulator element in another position.

Figure 1 schematically illustrates the front end of an aircraft turbojet engine which comprises a fan 1 which rotates about an axis XX′ in a casing 2. That part of said casing 2 situated forward of the fan 1 defines with a bullet 3, an air intake 4 into which atmospheric air flows in the direction of the arrow 5 to be delivered by the fan 1 into an annular duct 6 defined between the casing 2 and the hub 1*a* of the fan. Part of this air flows from the duct 6 into operative parts (not shown) of the turbojet engine, which parts comprise, in a manner known *per se*, one or more compressors, a combustion chamber, one or more turbines driving the compressor or compresors and the fan 1, and a propulsion nozzle. The rest of the air forms a secondary air flow which flows through an annular duct (not shown) surrounding the compressor or compressors, the combustion chamber and the turbine or turbines. The operation of the fan 1 and of the compressor or compressors is responsible for a very high noise level and this noise is propagated upstream through the air intake 4, and out into the atmosphere.

In order to make it possible to attenuate this noise when the aircraft is flying close to the ground, the air intake 4 is provided with fixed vanes 7 having inflatable blades 8. In the embodiment illustrated, the fan 1 is designed to operate with intake guide vanes. Each blade 8 comprises (Figure 5) two rigid elements 9, 10 forming respectively a leading edge and a trailing edge, in contact with which there are respectively maintained, by bars 11 and 12, the ends of a tubular elastic membrane 13 containing an inflatable bladder 14. The elements 9, 10 and the bars 11, 12 of each blade 8, are made of some suitable rigid material, for example metal; their external ends are attached to the casing 2 and their internal ends to the bullet 3 which latter they maintain in alignment with the axis of the hub 1*a* of the fan. The bladders 14 of all the blades 8 open onto a manifold 15 located in the casing 2 and can be supplied with compressed air, tapped from the delivery side of the compressor or compressors (not shown) through a line 16 equipped with a shut-off cock 17, which can be remote-controlled by the pilot.

In cruising flight, the bladders 14 are virtually deflated and the tubular membrane 13 of each blade 8 forms, between the leading edge element 9 and the trailing edge element 10, a pressure surface 18 and a suction surface 19. The blades 8 are radially disposed and equally angularly spaced as Figure 2 shows, their profiles being orientated in order to define passages 20 deflecting the incident air 5 in the direction of rotation 21 of the fan 1 (Figure 3) so that, in this deflated state, the fixed vanes 7 operate as guide vanes with respect to the blades 1*b* of the fan.

When the aircraft is flying close to the ground, the pilot opens the cock 17 so that the bladders 14 inflate and deform the tubular membranes 13 whose pressure and suction surfaces respectively adopt the configurations indicated at 18*a* and 19*a* in Figures 2, 4 and 5. In this inflated state, the pressure surface 18*a* of each blade 8 approaches the adjacent suction surface 19*a*

of a neighbouring blade 8, forming in each passage 20 a throat 22, the overall cross-sectional area of all the throats being sufficiently small to create a sonic throat in the airflow passing through each of them.

The soundwaves coming from the fan 1 and the compressor or compressors, are thus blocked at the sonic throats. The residual noise radiated upstream of the blading 7 stems on the one hand from the noise produced downstream and transmitted through the boundary layers and through the walls of the air intake 4 and the blading 7, and on the other hand from the noise emitted by the blading 7 itself. The noise transmitted by the boundary layers and by the walls is of low amplitude and can be still further reduced by using boundary layer suction devices. As far as the noise emitted upstream by the blading 7 is concerned, tests carried out by the applicants have shown that it is extremely low, the chief acoustic influence of the fan 7 being the emission of aerodynamic disturbances whose interaction with the blades 1*b* of the fan reinforces the noise produced by the latter, which noise is attenuated by the sonic throats.

Means, which have not been shown (for example a conventional bleed cock) are provided to enable the pilot to deflate the bladders 14 when the aircraft is cruising and there is no further need to attenuate the noise. The blades 8 then return to the configuration shown in Figure 3 and operate as an intake guide vanes in the conventional fashion in front of the fan. The air intake 4 is no longer than a conventional air intake provided with intake guide vanes.

Figure 6 illustrates an embodiment in which each blade of the blading ring 7 is equipped with a blower device whose chief function is to reduce the turbulence noise emitted downstream by this blading, which device is also able to a certain extent to reduce the thickness of the boundary layer at the level of the sonic throats and, consequently, to reduce the extent to which noise is propagated upstream. In the metal trailing element 10*a* of each blade 8, there are formed a longitudinal passage 23 and a slot 24, communicating with the former and opening onto the suction surface of said element 10*a*. The passages 23 in all the blades 8 are connected to a manifold 15 (Figure 1) so that when said manifold is supplied with compressed air in order to inflate the blades, as explained hereinbefore, part of the compressed air flows into the passages 23 and escapes through the slot 24 in the direction indicated by the arrow 25.

Figures 7 and 8 illustrate embodiments which make it possible to better adjust the shape of the pressure and suction surfaces of the blades 8, both in the deflated state, in order to produce profiles appropriate to an intake guide vanes arrangement, and in the inflated state, to produce passages 20 of convergent-divergent form which have a suitable profile. In these embodiments the rigid leading edge elements 9*b* and trailing edge elements 10*b* are connected by a rigid web 26 and are each equipped, at either side of said web, with longitudinal grooves 17. The tubular membrane 13 of Figures 5 and 6 is replaced by two membranes 28, 29 (Figure 7) or 28*a* and 29*a* (Figure 8), respectively forming the pressure surface 18 and the suction surface 19. Each of these membranes is provided with two roots 30 which are respectively located in two grooves 27 disposed on the same side of the web 26, and are held there by rigid bars 31, 32.

In Figure 7, the single bladder 14 in each blade 8 is replaced by three pairs of bladders, namely two central bladders 33 located at either side of the web 26 and two terminal pairs of bladders 34 and 35 situated respectively near the leading edge ond the trailing edge. Each pair of bladders is independently supplied with compressed air through a manifold such as manifold 15, making it possible to inflate the bladders in a differential fashion to produce the desired configuration of the pressure surface 18*a* and suction surface 19*a*. In another embodiment, each bladder could be supplied independently with compressed air in order, for example, to give the suction surface a more curved profile than the pressure surface.

In Figure 8 only one pair of bladders 36 is provided, but the membranes 28*a* and 29*a* have a thickness which varies from the leading edge to the trailing edge. The thinnest portions offer less resistance to elastic deformation so that the relative thicknesses of the various parts of the membranes can be chosen in order, in the inflated condition, to produce the desired pressure and suction surfaces. In this embodiment the two bladders can be differentially inflatable.

If it is desired to be able to regulate the pressure of inflation of the blades 8, so that in conditions of flight in which it is necessary to attenuate noise propagating upstream through the air intake 4 the throats 22 form sonic throats whilst at the same time creating only minimal losses in the flow, it is an easy matter to arrange in the line 16, or in the manifold 15, a variable expansion valve or variable pressure bleed valve. Figure 9 shows, by way of example, a variable pressure relief valve 37 arranged in the line 16 downstream of the shut-off cock 17.

The pressure relief valve 37, of a kind well known *per se*, is illustrated in detail in

Figures 10 and 11. It comprises a body 38 with a bore 38*a* in which there slides a piston 39 biased by springs 40 and 41 and equipped with a bleed seat 42, plus a valve member 43 loaded by the input pressure and by a light spring 44, onto the seat 42. The head 43*a* of the valve member 43 has a diameter less than that of the bore 38*a* so that it determines therein an annular chamber 45 communicating with the input 46 of the valve through passages 43*b* formed in the valve member 43 itself. The pressure in the line 16 thus acts on the one hand on the valve member 43 and on the other on the piston 39, and tends to push them towards the right (Figures 10 and 11) against the action of the springs 40 and 41. The valve member 43 is equipped with a collar 43*c* which limits its displacement towards the right by co-operation with the body 38 so that the piston is only subjected to the pressure acting, in the chamber 45, on the annular area 39*a* surrounding the bleed seat 42. When the effect of this pressure exceeds the predetermined load of the springs 40 and 41 th piston 39 continues its travel to the right (Figure 11) so that compressed air from the line 16 flows past the seat 42, which is now uncovered, and through a passage 39*b* in the piston, to escape through the discharge orifice 47 of the valve. The result is a reduction in the pressure in the line 16, downstream of the cock 17; when this pressure drops to a sufficiently low level, the springs 40 and 41 push back the piston 39 so that the seat 42 is again in contact with the valve head 43*a* and so on.

The pressure in the line 16, downstream of the cock 17, is thus determined by the predetermined load of the springs 40 and 41. These seat against an output connection 48 screwed onto a threaded portion 38*b* of the body 38 and locked by a locknut 49. To regulate the inflation pressure of the blades 8, it is therefore merely necessary to release the locknut 49 and to screw down or slack off the connection 48 in order to modify the load of the springs.

In the embodiment shown in Figure 9 the air bled off from the output 47 of the valve 37 escapes to the outside of the casing 2. In other embodiments, the air could be bled into the duct 6.

In other embodiments (not shown) the cock 17 could be replaced by a multi-way cock, remote-controlled and connected to the manifold 15 through several output lines provided with pressure-regulator elements set to different pressures. It would then be possible, by operating the cock, to inflate the blades 8 to different pressures in order to adapt their profiles to various flight conditions (take-off, approach, descent, etc.).

The embodiments described are purely examples and can be modified. In particular, in the case where the fan is designed to operate without any intake guide vane, the blades 8 will preferably be orientated along the direction of the incident flow 5 (Figure 1). They would then not have any areodynamic function in the deflated condition and would simply act as supporting arms for the boss 3. In the inflated condition, they would attenuate the noise as in the aforedescribed embodiment and could be equipped with boundary layer suction devices on both faces. It should be noted that in all cases, the inflatable blading 7 occupies a much shorter longitudinal space in the intake than do known retractable sound-damping devices.

WHAT WE CLAIM IS:—

1. An air intake device for supplying air to a fan or compressor, said device having an inflatable structure designed to create a sonic flow in order to attenuate the noise component propagating upstream, said structure comprising a plurality of blades whose lateral faces are constituted by elastic walls capable of being deformed under the action of at least one inflatable body in order to create a sonic throat or restriction between one face of each blade and the adjacent face of a neighbouring blade, the throat or restriction acting to attenuate noise propagating upstream.

2. An intake device as claimed in claim 1, provided with means for controlling air flow around the blades.

3. An intake device as claimed in claim 2, in which the air flow is controlled by blowing air from the trailing edges of the blades.

4. An intake device as claimed in any one of claims 1 to 3, in which the blades are orientated so that the fixed blading, in the deflated state, operates as an intake diffuser with respect to the fan or compressor.

5. An intake device as claimed in any one of claims 1 to 4, in which the leading edge and trailing edge of each blade are formed by rigid elements serving as supports for a bullet, or other component disposed coaxially with respect to the intake.

6. An intake device as claimed in claim 5, in which each blade includes means for rigidly connecting said rigid elements.

7. An intake device as claimed in any one of the preceding claims, in which each blade includes several differentially inflatable bodies.

8. An intake device as claimed in any one of the preceding claims, in which the elastic walls of each blade have a thickness which varies from the leading edge to the trailing edge.

9. An intake device as claimed in any one of the preceding claims, provided with means for regulating the pressure of infla-

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tion of the inflatable bodies.

10. An intake device as claimed in claim 9, provided with means for pre-selecting the inflation pressure.

11. An intake device for supplying air to a fan or compressor substantially as hereinbefore described with reference to the accompanying drawings.

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3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG. 1

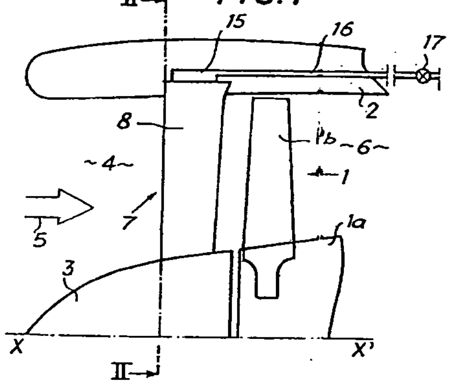

FIG. 2

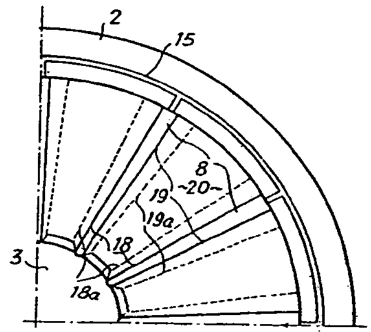

FIG. 3

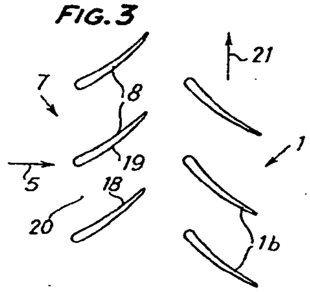

FIG. 4

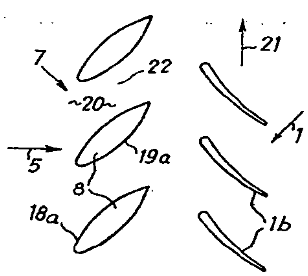

FIG. 5

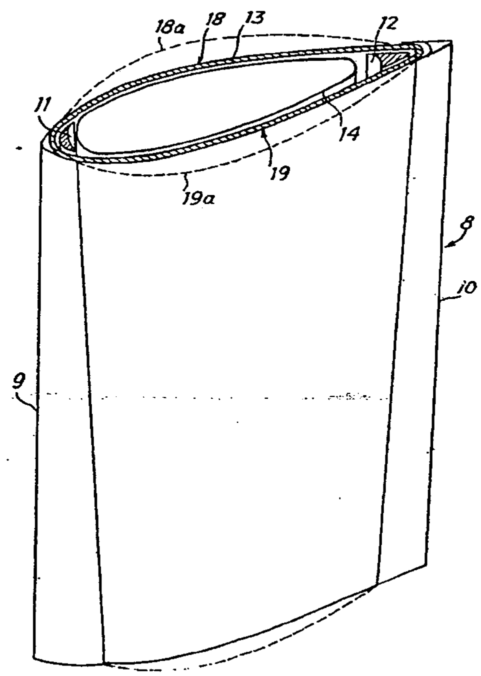

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FIG.6

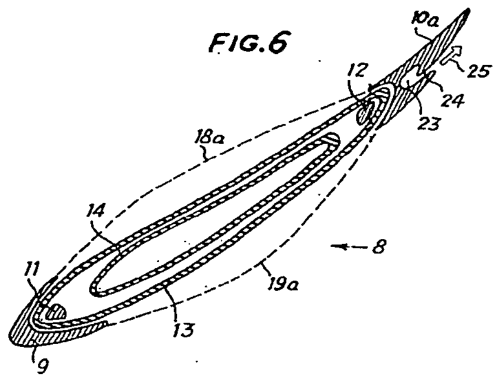

FIG.7

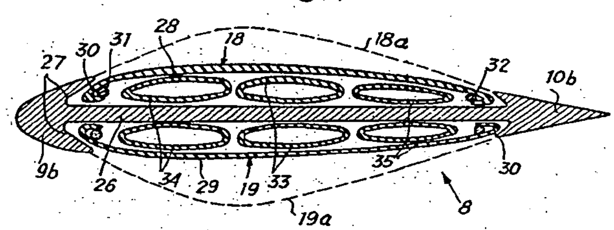

FIG.8

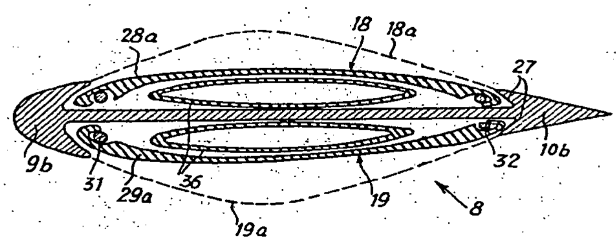

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FIG.: 9

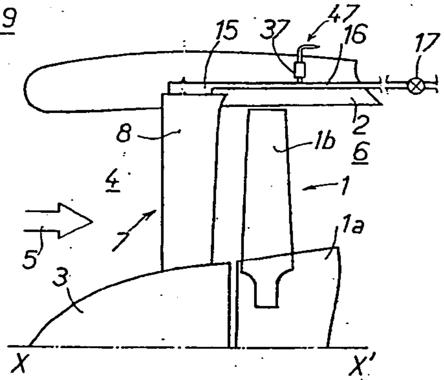


FIG.: 10

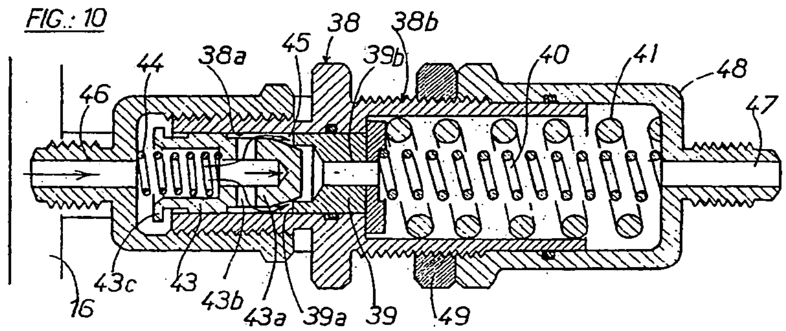
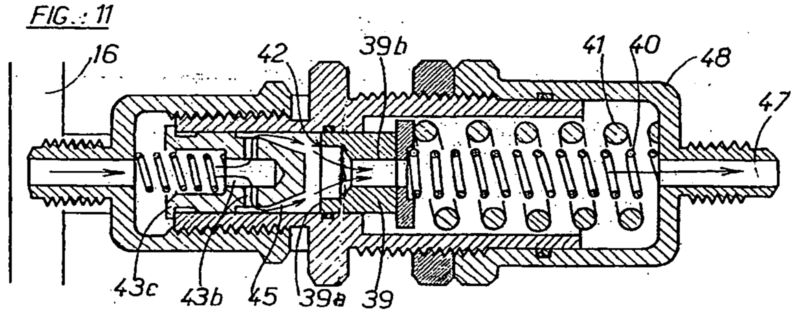


FIG.: 11



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